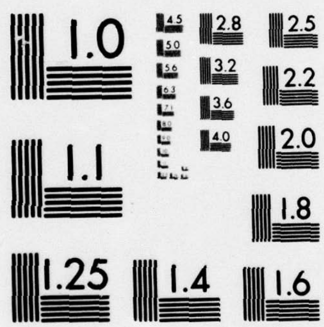
AD-A039 282 FOREIGN TECHNOLOGY DIV WRIGHT-PATTERSON AFB OHIO F/G 20/12
EFFECT OF PHASE TRANSITION OF SHF-CONDUCTIVITY OF THIN GERMANIU--ETC(U)
NOV 76 V P ZAKHAROV, V N CHUGAYEV, V I ZALIVA

UNCLASSIFIED FTD-ID(RS)I-1549-76 NL

| OF |

AD
A039282

END
DATE
FILMED
5-77



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AD-A039282

FTD-ID(RS)I-1549-76

1

NW

FOREIGN TECHNOLOGY DIVISION

EFFECT OF PHASE TRANSITION ON SHF-CONDUCTIVITY OF THIN GERMANIUM FILMS

by

V. P. Zakharov, V. N. Chugayev, V. I. Zaliva

FTD ID(RS)I-1549-76

EDITED TRANSLATION

FTD-ID(RS)I-1549-76 30 November 1976

FTD-76-C-001250

EFFECT OF PHASE TRANSITION ON SHF-CONDUCTIVITY OF THIN GERMANIUM FILMS

By: V. P. Zakharov, V. N. Chugayev, V. I. Zaliva

English pages: 11

Source: Fizika i Khimiya Obrabotki Materialov, Nr 4, 1972, PP. 149-152.

Country of origin: USSR
Translated by: Marilyn Olaechea
Requester: FTD/PDRR
Approved for public release; distribution unlimited.

U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere. When written as ё in Russian, transliterate as yё or ё. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

GREEK ALPHABET

Alpha	Α	α	*α*	Nu	Ν	ν	
Beta	Β	β		Xi	Ξ	ξ	
Gamma	Γ	γ		Omicron	Ο	ο	
Delta	Δ	δ		Pi	Π	π	
Epsilon	Ε	ε	*ε*	Rho	Ρ	ρ	*ρ*
Zeta	Ζ	ζ		Sigma	Σ	σ	ς
Eta	Η	η		Tau	Τ	τ	
Theta	Θ	θ	ϑ	Upsilon	Υ	υ	
Iota	Ι	ι		Phi	Φ	φ	ϕ
Kappa	Κ	ϰ	κ *κ*	Chi	Χ	χ	
Lambda	Λ	λ		Psi	Ψ	ψ	
Mu	Μ	μ		Omega	Ω	ω	

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English
sin	sin
cos	cos
tg	tan
ctg	cot
sec	sec
cosec	csc
sh	sinh
ch	cosh
th	tanh
cth	coth
sch	sech
csch	csch
arc sin	$\sin^{-1}$
arc cos	$\cos^{-1}$
arc tg	$\tan^{-1}$
arc ctg	$\cot^{-1}$
arc sec	$\sec^{-1}$
arc cosec	$\csc^{-1}$
arc sh	$\sinh^{-1}$
arc ch	$\cosh^{-1}$
arc th	$\tanh^{-1}$
arc cth	$\coth^{-1}$
arc sch	sech^{-1}
arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

GRAPHICS DISCLAIMER

All figures, graphics, tables, equations, etc. merged into this translation were extracted from the best quality copy available.

EFFECT OF PHASE TRANSITION ON SHF-CONDUCTIVITY OF THIN GERMANIUM FILMS

V. P. Zakharov, V. N. Chugayev, V. I. Zaliva

(Kiev)

ABSTRACT Studied is the change in absorption of SHF-radiation by thin germanium films in which the growth of crystals is observed during irradiation by powerful light pulses. Established is the existence of an intermediate phase on the interface of the growing crystal and amorphous film. The SHF-conductivity of this phase is close to the conductivity of molten germanium. The amorphous film-crystal phase transition begins at a temperature of ~300°C.

Estimated is the magnitude of activation energies of the phase transition in the amorphous germanium film.

Amorphous semiconductors have recently become the object of very thorough study - both theoretical and experimental. This interest is explained by the fact that the break-down in the long-range order of amorphous semiconductors does not have a substantial effect on their energy zone structure, although it leads to the development of a number of characteristic properties. The most structure-sensitive parameter in such subjects is conductivity. A disturbance in the long-range order in the arrangement of atoms leads to the development of additional liquid dispersion, which is significant in comparison to the usual back-ground dispersion at room temperatures. The length of the free path and, consequently, the mobility of the charge carriers, will be determined by the degree of disorder in the amorphous semiconductors [1-3]. A break-down in the long-range order also leads to the development of fluctuation levels for both donor and acceptor levels, the ratio of which for different substances can vary by several orders of magnitude.

Thin germanium films, obtained by vacuum application on unheated, unstructured substrata, are a typical representation of amorphous semiconductors. These films are not as dense as crystals;

their grain size is smaller than 100 Å, and as a rule they are characterized by hole conductivity with low carrier mobility (100-200 $cm^2/V \cdot s$).

Recrystallization of germanium films leads to a sharp increase in their conductivity. As the crystals increase up to ~100 μm the electron type of conductivity is restored, if n-type germanium is used as the original material [4].

The growth of crystals in an amorphous germanium film can be achieved by electron-beam treatment or by the focused radiation of a continuous laser [5-7]. Similar structural changes occur in "free" germanium films on grid-holders, when acted upon by powerful pulsed light radiation. Information on the concentration and mobility of current carriers in films can be obtained by studying their absorption of SHF-radiation. The growth of crystals in amorphous germanium films should obviously lead to a change in the absorption of SHF-radiation both in the growth process and in the final state as compared to the beginning. Most important is information on the intermediate states which occur in the film during the phase transition of amorphous film to crystal.

Studied in [8, 9] was the growth of crystals in amorphous germanium films acted upon by pulsed and intermittent laser

radiation. During irradiation of the germanium film by a powerful focused light beam the growth of crystals is observed in a region of the film which considerably exceeds the region of the direct radiation effect. Determined as a result were the growth rates of crystals in portion of the film bounded by the cell dimensions of the holding grid on which the film rested. Because of the possible scatter in the beginning of crystal growth at different points on the film, which may be caused by the finite rate of propagation of activation energy over the film, these data can be regarded as averaged for a number of elementary acts of crystal growth.

In order to avoid this in the present work we used a method of simultaneous activation of the phase transition by irradiation of significant areas of the film by pulsed gas-discharge lamp IFP-800. To study the absorption of SHF-radiation by the germanium film during the phase transition, it was placed in a three-centimeter waveguide of rectangular cross section in a position perpendicular to its axis between the radiator and the detector. The film was irradiated through an opening in the wall of the waveguide covered with a semi-transparent metal grid or glass with a conductive transparent coating. The signal from the SHF-radiation detector entered the input of the oscillograph, whose scanning was synchronized with the triggering of the lamp pulse. Amorphous germanium films were obtained by spray application in a vacuum onto unheated glass substrata. These

were later rinsed in water and placed on capron holding grids.

Electron-microscope studies of the germanium films irradiated by a pulse lamp revealed the growth of single crystals in them. The dimensions and direction of growth of these crystals was determined by the cell geometry of the holding grid. At the proper levels of the light flux from the lamp the average dimensions of the single crystal grown were ~10 μm. For similar enlargements and crystal dimensions (from 20-30 Å to 10-20 μm) the conductivity of germanium films increases several orders in direct current [7].

Figure 1a and b show typical oscillograms of the change in absorption of the power of the SHF-wave by the film in which the phase transition is observed and in the recrystallized film during heating by the radiation pulse of the lamp. The radiation power of the lamp pulse in both cases was the same. In comparing oscillograms there is a noticeable difference in the change of absorption of SHF-wave power by the films, which is primarily determined by the conductivity of the latter as a function of their original structure. If the change in conductivity of the recrystallized film during irradiation by the lamp pulse characterizes the usual heating, then the phase transition in the amorphous film substantially changes its conductivity. The beginning of the phase transition in the film is related to the point on the oscillogram where there is a sharp change

in the slope of the curve describing the absorption of SHF-radiation by the film in time. The change in absorption of the SHF-radiation by the amorphous germanium film during irradiation by the lamp pulse occurs in the following sequence; increase due to heating, sharp increase of phase transition in time, relatively rapid decline directly after end of phase transition, and exponential decline, which characterizes the cooling of the film in the recrystallized state.

The time of the beginning, the length of the phase transition, and the rate of growth of crystals in the film, determined by SHF-measurement, were compared to the change in its optical density under analogous conditions of irradiation by a pulsed lamp (Fig. 1c). The technique of measuring the change in the optical density of the film is described in [9], where it is shown that the end of the phase transition in the film coincides in time with the moment of stabilization of its level of optical density. These prameters of the studied process determind by two independent methods agreed with a degree of accuracy sufficient to assure that the change in the SHF-absorption and optical density of the film was caused by a single factor - the growth of crystals in the film.

Despite the noticeable change in absorption of SHF-radiation during the phase transition, the level of absorption by the

recrystallized zone at the end of the lamp pulse had undergone an irreversible increase of only 2-3 times, i.e., it was incomparably lcwer than conductivity with respect to direct current. The temperature dependences of SHF-absorpticn by amcrphous layers and their conductivities with respect to direct current, measured during slow heating in a thermostat, were also different.

These differences can be explained by the fact that the resistance of amorphous structures measured by direct current are determined by high-resistance interfaces between relatively ordered grains, while the most conductive portions, i.e., the grains, play the major role in SHF-adsorption.

It remains to be explained what causes the sharp, yet reversible, increase in absorption of SHF-radiation by the film during the phase transition. This fact can be explained by the presence of an intermediate phase during the prccess of crystal growth, whose conductivity differs significantly from that of the germanium film in the amorphcus and recrystallized state. We know that during melting of germanium its conductivity acquires a metallic nature. Melting of films in the center of the grid-holder cells was achieved by specially selected conditions in the experiment. During a ccntinuous increase in the temperature of the film melting in the center of the cell begins only when the growth cf the crystals in it

ends (Fig. 2).

The advent of the liquid phase causes a further sharp change in the absorption of SHF-radiation by the germanium film (Fig. 3). Despite the fact that only a small portion of the total area of the film is melted, the change in absorption of the SHF-radiation caused by it is comparable with that which occurs during the growth of crystals. In repeated irradiation of recrystallized films the nature of the change in absorption by them of SHF-radiation coincides with the behavior of their temperature change. Thus, it is logical to assume that during the process of ordering of the film structure there develops an intermediate phase, which in its properties is similar to molten germanium, and this phase is localized near the moving front of the growing crystals. When the growth of the crystals ends, just as at the end of melting, absorption of SHF-radiation by the film decreases sharply, changing to a curve which describes the cooling of the recrystallized film.

The initial course of the film heating curve before the beginning of the growth of crystals in it and the increase in absorption of SHF-radiation related to this lets us estimate the temperature which corresponds to the beginning of the phase transition. For this purpose the change in absorption of SHF-radiation by a film during slow thermal heating was studied.

Determined as a result was the temperature at which the increase in absorption of SHF-radiation corresponded to the same change for a film heated by a pulsed lamp up to the beginning of the phase transition in it. The temperature thus estimated for the beginning of the phase transition turned out to be ~300°C. The energy absorbed by the film before the beginning of the phase transition constituted a value of 10^{-3} cal/cm^2, which is sufficient for heating a film 500 Å thick to 300°C. Considered in this case was the heat removal of energy to the coils of the holding grid, the reflection of lamp radiation from the surface of the film, and the nature of the energy distribution of the lamp in space.

Thus, by studying SHF-conductivity, which is one of the most structurally sensitive parameters of thin films, we can get some idea of the processes which accompany the rearrangement of the structure in them during phase transitions. The rather high time resolution of the given method (~10^{-6} s) makes it possible to study the kinetics of phase transitions in thin films of metals and semiconductors.

Received 5 May 1970

Bibliography

1. Губанов А. И. Квантово-электронная теория аморфных проводников, М.—Л., АН СССР, 1963.
2. Clark A. H. Electrical and Optical Properties of Amorphous Germanium. Physical Review, 1967, 154, No. 3, 750.
3. Moorjani K., Feldman C. Electrical Properties of Amorphous Semiconductors. Reviews of Modern Physics, 1964, 36, No. 4, 1042.
4. Naber C. T. Recristallisation of Germanium Thin Films of Insulating Substrates by Electron Beam Zone Melting. J. Electrochem. Soc., 1967, 114, No. 4, 406.
5. Gilbert G. B., Poehler T. O., Miller C. F. Study of Electron Bombardment of Thin Films, Journ. of Appl. Phys., 1961, 32, No. 8, 1597.
6. Namba S. Crystallization of Vacuum-Evaporated Germanium Films by the Electron — Beam Zone — Melting Process. J. Appl. Phys., 1966, 37, No. 4, 1929.
7. Захаров В. П., Чугаев В. Н. Рекристаллизация тонких пленок германия излучением ОКГ непрерывного действия. Физ. и хим. обраб. материалов, 1970, № 6, 126.
8. Захаров В. П., Чугаев В. Н. Рост монокристаллов в тонких пленках германия при взаимодействии их с излучением лазера. Физ. и хим. обраб. материалов, 1968, № 4, 76.
9. Захаров В. П., Польский Ю. М., Чугаев В. Н. Кинетика структурных изменений в тонких пленках германия и углерода при взаимодействии их с излучением ОКГ. Физ. и хим. обраб. материалов, 1970, № 5, 55.

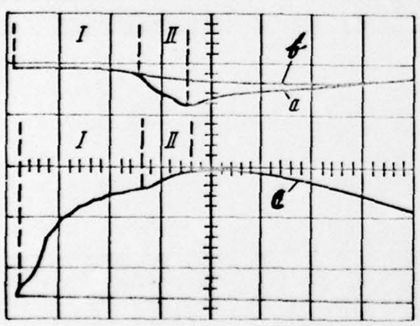


Fig. 1.

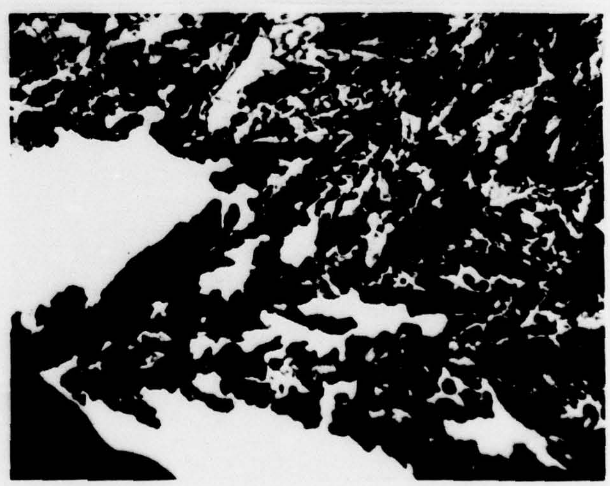


Fig. 2.

Fig. 3.

Fig. 1. Change in absorption of SHF-radiaticn (a, b) and optical density (c) of germanium films during pulsed illuminiation: I - time interval of film heating prior to phase transitions, II - duration of phase transition (scanning period 100 μm/cm).

Fig. 2. Photomicrograph of molten portion of recrystallized germanium film (1200).

Fig. 3. Change in absorption of SHF-radiation by germanium film irradiated by high intensity pulse. I and II - see Fig. 1; III - time of existence of liquid phase (scanning period 1 μs/cm.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER FTD-ID(RS)I-1549-76	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) EFFECT OF PHASE TRANSITION ON SHF-CONDUCTIVITY OF THIN GERMANIUM FILMS		5. TYPE OF REPORT & PERIOD COVERED Translation
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) V. P. Zakharov, V. N. Chugayev, V. I. Zaliva		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Foreign Technology Division Air Force Systems Command U. S. Air Force		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE 1972
		13. NUMBER OF PAGES 11
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

20; 11

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

DISTRIBUTION LIST

DISTRIBUTION DIRECT TO RECIPIENT

ORGANIZATION	MICROFICHE	ORGANIZATION	MICROFICHE
A205 DMATC	1	E053 AF/INAKA	1
A210 DMAAC	2	E017 AF/RDQLR-W	1
B344 DIA/DS-4C	8	E404 AEDC	1
C043 USAMIIA	1	E408 AFWL	1
C509 BALLISTIC RES LABS	1	E410 ADTC	1
C510 AIR MOBILITY R&D LAB/FIO	1	E413 ESD	2
		FTD	
C513 PICATINNY ARSENAL	1	CCN	1
C535 AVIATION SYS COMD	1	ETID	3
C557 USAIIC	1	NIA/PHS	1
C591 FSTC	5	NICD	5
C619 MIA REDSTONE	1		
D008 NISC	1		
H300 USAICE (USAREUR)	1		
P005 ERDA	2		
P055 CIA/CRS/ADD/SD	1		
NAVORDSTA (50L)	1		
NAVWPNSCEN (Code 121)	1		
NASA/KSI	1		
544 IES/RDPO	1		
AFIT/LD	1		